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The Relative Impact Framework for Evaluating Coal Combustion Residual Surface Impoundment Closure Options: Applications and Lessons Learned†

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ABSTRACT

In response to the U.S. Environmental Protection Agency's new rule regarding the disposal of coal combustion residuals (CCRs), many utilities need to re-examine their waste disposal practices and make decisions regarding if and how unlined surface impoundments (SIs) should be closed. The two primary options for closing SIs are in-place closure, with capping and engineering controls, and excavation of the CCR for transport to and re-disposal in a lined landfill. To help inform closure option decisions, we supported the Electric Power Research Institute's development of a practical, science-based decision framework that comprehensively evaluates the potential impacts to human health and the environment associated with SI closure alternatives. We have applied this framework to several sites and have performed a detailed sensitivity analysis of individual parameters on the framework results. Based on these applications, we developed a set of lessons learned that can be used to scope and streamline further SI closure option assessments.

1. Introduction

On 17 March 2015, the U.S. Environmental Protection Agency (US EPA) published the final coal combustion residual rule ("the CCR Rule"; US EPA, 2015). A key focus of the CCR Rule is on unlined surface impoundments (SIs) due to their potential to impact human health and the environment. Publication of the CCR Rule has coincided with increasing public scrutiny of SIs, due in part to several high-profile releases into public waterways. In response to new regulations contained in the CCR Rule and increasing public pressure, many utilities are evaluating closure options for unlined SIs. There are two main options for surface impoundment closure: closure-in-place (CIP), which involves capping the unlined SI, and closure-by-removal (CBR), which involves excavation of the CCR and transport and disposal of that CCR in new, lined landfill cells. To assist utilities with evaluating and communicating SI closure options, we served as principal investigators on an Electric Power Research Institute (EPRI) project that developed a systematic approach for evaluating and comparing the beneficial and adverse impacts of CIP and CBR ("the Framework") (EPRI, 2016a). This article presents a summary of the lessons learned from several implementations of the Framework.

2. Relative Impact Framework

Under the Framework, a set of "pathways" are evaluated for each closure scenario, with each pathway representing an environmental transport medium, a safety concern, or a human or ecological risk factor. The Framework specifically details assessment methods for six pathways (groundwater, surface water, air, green and sustainable remediation [GSR], community and worker safety, and direct contact with CCR), although the flexibility of the Framework allows for consideration of other pathways (e.g., catastrophic failure of SIs). GSR is a pathway that evaluates the use of resources (e.g., materials and water consumption) and energy. The Framework also details a set of "outcome metrics" for each pathway, with each outcome metric describing a specific way to quantify the closure impacts for a pathway (e.g., comparing modeled concentrations with a regulatory benchmark). The outcome metrics range from screening-level evaluations to highly detailed human health and ecological risk assessments. Finally, the Framework describes how the assessment

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results for each pathway can be integrated to assist with planning and communication of SI closure options.

3. Framework Applications

3.1. Framework application experience

We applied the Framework and performed associated analyses in support of utilities' closure assessment planning. Example assessments are briefly described below.

Quantitative assessment of a single SI. On behalf of a utility, we evaluated the CIP and CBR closure options at a single SI in the southeastern United States. This screening-level Framework assessment considered the groundwater, surface water, air, GSR, and safety pathways.

Quantitative assessment of a hypothetical SI. In collaboration with EPRI, we developed a hypothetical, yet realistic SI that could be used to test the Framework. This assessment used outcome metrics that were more refined than a screening-level assessment, but less refined than a risk assessment, and considered the groundwater, surface water, air, GSR, and safety pathways. A full description of this assessment is provided in an EPRI (2016b) report.

Sensitivity analyses on a hypothetical SI. In collaboration with EPRI, we performed a set of sensitivity analyses on the hypothetical SI described above. These analyses tested the impacts of modifying key factors involved in SI closure (e.g., the amount of CCR in the SI, the characteristics of the groundwater, the distance between closure activities and the local community). A full description of the sensitivity analyses are provided in an EPRI (2016b) report.

Qualitative assessment of 10 SIs. In collaboration with EPRI, we qualitatively applied the Framework to 10 SIs by leveraging the hypothetical site and associated sensitivity analysis results. This evaluation leveraged the idea that SIs that had similar features to the hypothetical site and could be evaluated based on a comparison of their site and closure features (e.g., CCR volume, length of haul roads, dump truck capacity) to the range of site and closure features tested in the hypothetical site sensitivity analyses. A full description of this assessment is provided in an EPRI (2016c) report.

3.2. Lessons learned

We have developed a set of lessons learned based on the initial Framework applications described in Section 3.1. These lessons provide insight for utilities that are planning future SI closure option assessments.

3.2.1. Focused planning at the start of an assessment saves time overall

Framework assessments can be lengthy, complicated processes, and organization is important for avoiding rework and inconsistencies. Because of the broad scope of pathways that can be included in a Framework assessment, it is likely that different teams of people will be working independently on different pathway assessments. Prior to each team beginning work, it is important to fully detail the closure schedule and associated work elements involved in each of the closure options, the geographic location of current and new site features (e.g., roads, SIs, landfills, receptors), and the set of assumptions that will be used to simplify the modeling or fill data gaps. We have found that it is best to select assumptions that are realistic, yet conservative, in order to model the closure options in a way that is most useful for decision making. Additionally, if the Framework assessment is only focused on comparing closure options, it may be possible to eliminate modeling of activities that are common to all closure options. However, if the assessment results are being compared with regulatory benchmarks, elimination of some activities may not be possible. Finally, at the outset of the assessment, it is important to define a threshold at which model results will be considered equivalent to zero. As an example, it is possible that model-predicted surface water concentrations for both closure options are very small (below relevant aqueous surface water standards and potentially even below laboratory detection limits), but still orders of magnitude different from each other. Without a zero threshold, a comparison of these surface water concentrations (e.g., ratios of the surface water concentration under CIP vs. CBR) could falsely show that one closure option is far more beneficial than the other, even though concentrations for both closure options are essentially nonmeasurable.

3.2.2. Air, GSR, and safety usually more adverse under CBR

The set of assessments that we have completed show similar characteristics in the air, GSR, and safety pathways. These pathways typically show adverse impacts for both CBR and CIP, with the most adverse impacts for the CBR scenario.

3.2.3. Groundwater results are pivotal to decision making

The air, GSR, and safety pathways tend to show adverse impacts for both closure options, and the surface water impacts tend to be minimal for both closure options. However, groundwater assessments show that both CIP and CBR provide significant beneficial impacts to groundwater quality compared with continued SI operations and that neither of the closure options is always more beneficial, with respect to downgradient groundwater quality, than the other. These results are consistent with the US EPA position in the CCR Rule that both closure options can be equally protective, provided they are implemented properly. Depending on the constituents of interest, the size of the SI, the time required to complete the closure option, and the hydrogeological conditions, both CIP and CBR have potential to provide a greater degree of contaminant reduction in downgradient groundwater monitoring wells compared with the other option. Additionally, the level of groundwater protection provided by the two closure options is similar for all the assessments that we have conducted. For many assessments, the relative percent difference between the downgradient time-weighted average constituent concentrations under CIP and CBR was less than 10%. Moreover, it is possible that groundwater corrective actions, if instituted as part of a combined remedy with CIP, would result in a greater and more rapid reduction of contaminant concentrations in downgradient groundwater than CBR in some assessments.

3.2.4. Outcome metrics can influence interpretation of assessment results

The choice of outcome metric can greatly influence the interpretation and utility of Framework assessment results. For example, an air pathway screening level assessment may use a simple outcome metric such as the quantity of particulate emissions from each closure option, while a more refined assessment might evaluate downwind air concentrations in residential areas and how these compare with regulatory benchmarks. In this example, it is possible for air emissions under CIP and CBR to differ greatly, which would suggest that there is an important difference between the closure scenarios. However, the downwind air concentrations for both closure options in this example could be below the regulatory benchmark, which would suggest that the differences between the closure scenarios are not important from a regulatory perspective. This demonstrates that the outcome metrics chosen must align with the assessment needs and goals.

3.2.5. Key factors influence the relative impacts of CIP vs. CBR

Several key factors had a large influence on the relative impacts of CIP vs. CBR in the Framework assessments we have conducted to date. Overall, the most influential factor has been the closure timeline for CIP vs. CBR. The longer timeline for CBR, compared with CIP, was associated with greater or longer transport of materials (e.g., CCR, soil, and other capping materials) through residential areas, as well as greater use of resources (e.g., energy, materials, and staff), resulting in larger CBR impacts for the air, GSR, and safety pathways. Surprisingly, the closure timeline was also the most influential factor for the groundwater pathway.

The location of the landfill for the CBR option and the location of receptors (e.g., residential areas) for both closure options were also key influences on the relative impacts of CIP vs. CBR. If the landfill was placed on-site (i.e., within the same site as the SI), there were significantly lower community safety impacts and residential air quality impacts associated with CBR than if the landfill was located off-site. An on-site landfill could therefore result in the CIP and CBR options having more similar air and safety impacts. Similarly, if receptors (e.g., residential and commercial areas of concern) were located near the SI, the groundwater and air impacts of both closure options were likely to be greater than if these receptors were located far from the SI. For the air pathway, proximity of receptors to haul roads and the landfill were also important, as there can be large fugitive dust emissions from these sources during SI closure.

4. Conclusions

The Framework has proven to be a useful tool to inform SI closure decisions. Use of the Framework allows for analysis of the minimization of both short- and long-term impacts to human health and the environment. Additionally, results of a Framework assessment can be readily used to inform environmental impact statements and communications between industry, regulators, and the public. The Framework assessments that we have conducted to date show that the air, GSR, and safety pathways typically have more adverse impacts under CBR; the surface water impacts under both CBR and CIP are minimal; and the groundwater impacts are very site-specific and, therefore, are pivotal to identifying the preferred closure option.

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